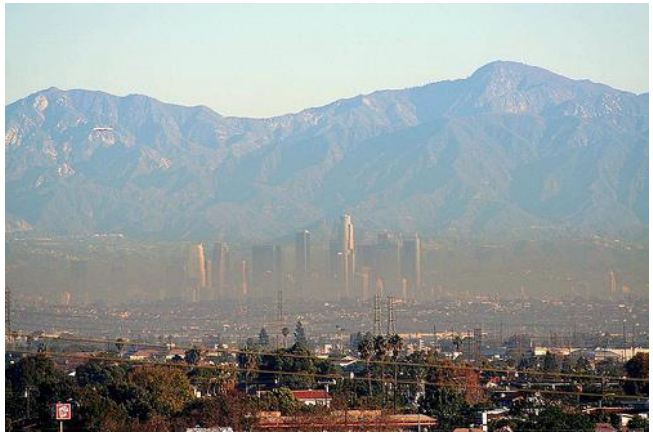
Cleaning up La-La Land:

Alternative Facts or a New Reality?



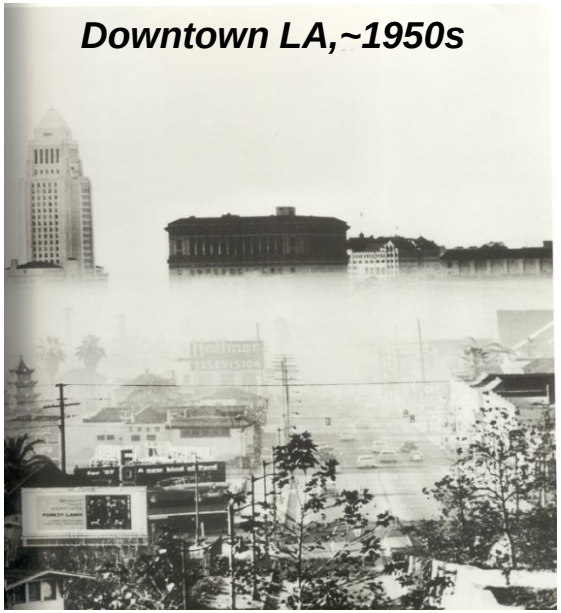
Ed Avol
Department of Preventive Medicine
Keck School of Medicine of USC
avol@usc.edu

Our Path Today…

- The (California) Children's Health Study (CHS)
- How air quality changed … and why
- How AQ changes affected children's health
- So what? (the policy part …)

The Public Health Question…(ca. 1990)

Does outdoor air pollution cause *permanent* health effects?

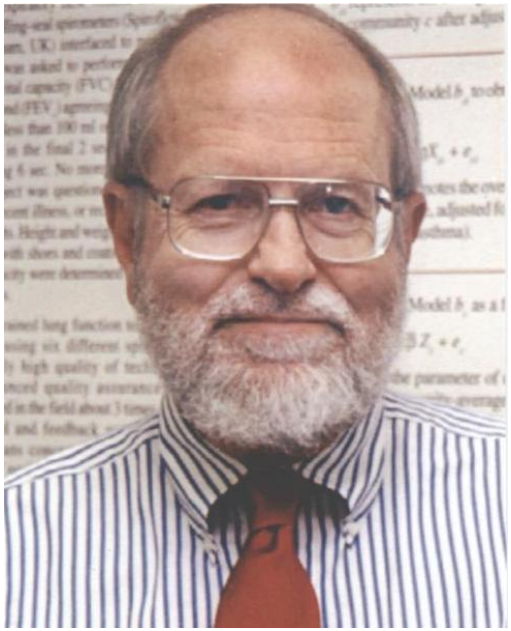


The USC Children's Health Study

(est. 1992)

Original PI:

John Peters



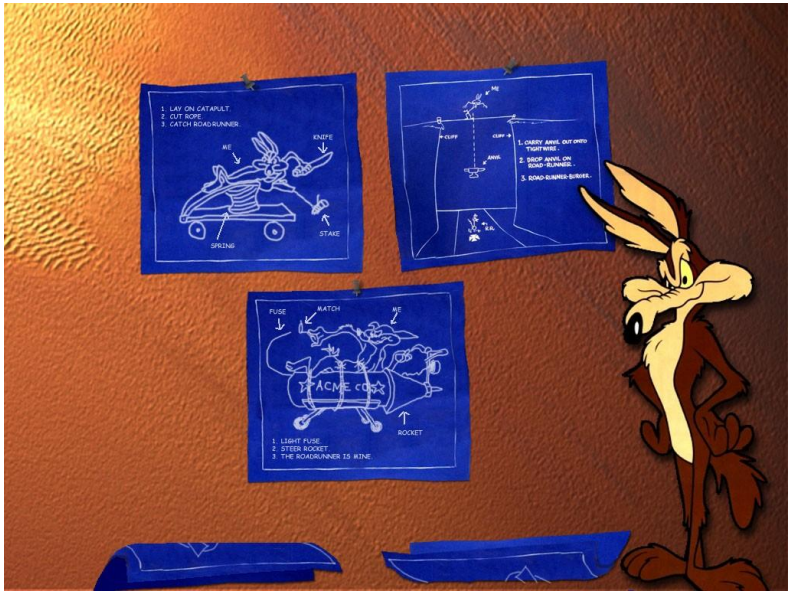
Original Co-Investigators

Ed Avol
Stephanie London
Bill Navidi
Duncan Thomas

Original Advisors

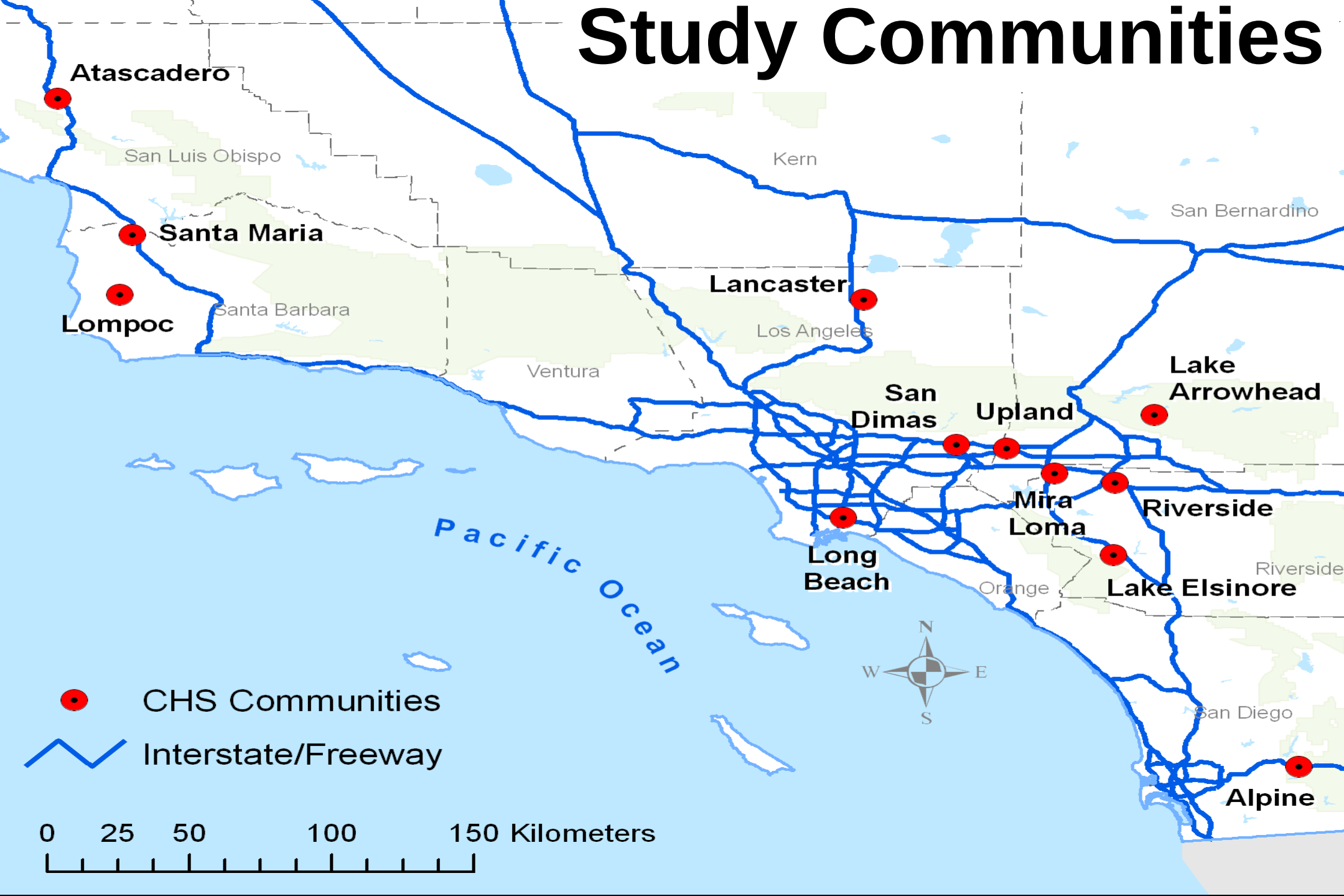
David Bates
Glen Cass
Mort Lippmann
Jon Samet
Frank Speizer
Jack Spengler
Jim Whittenberger
Arthur Winer
Scott Zeger

The Plan…

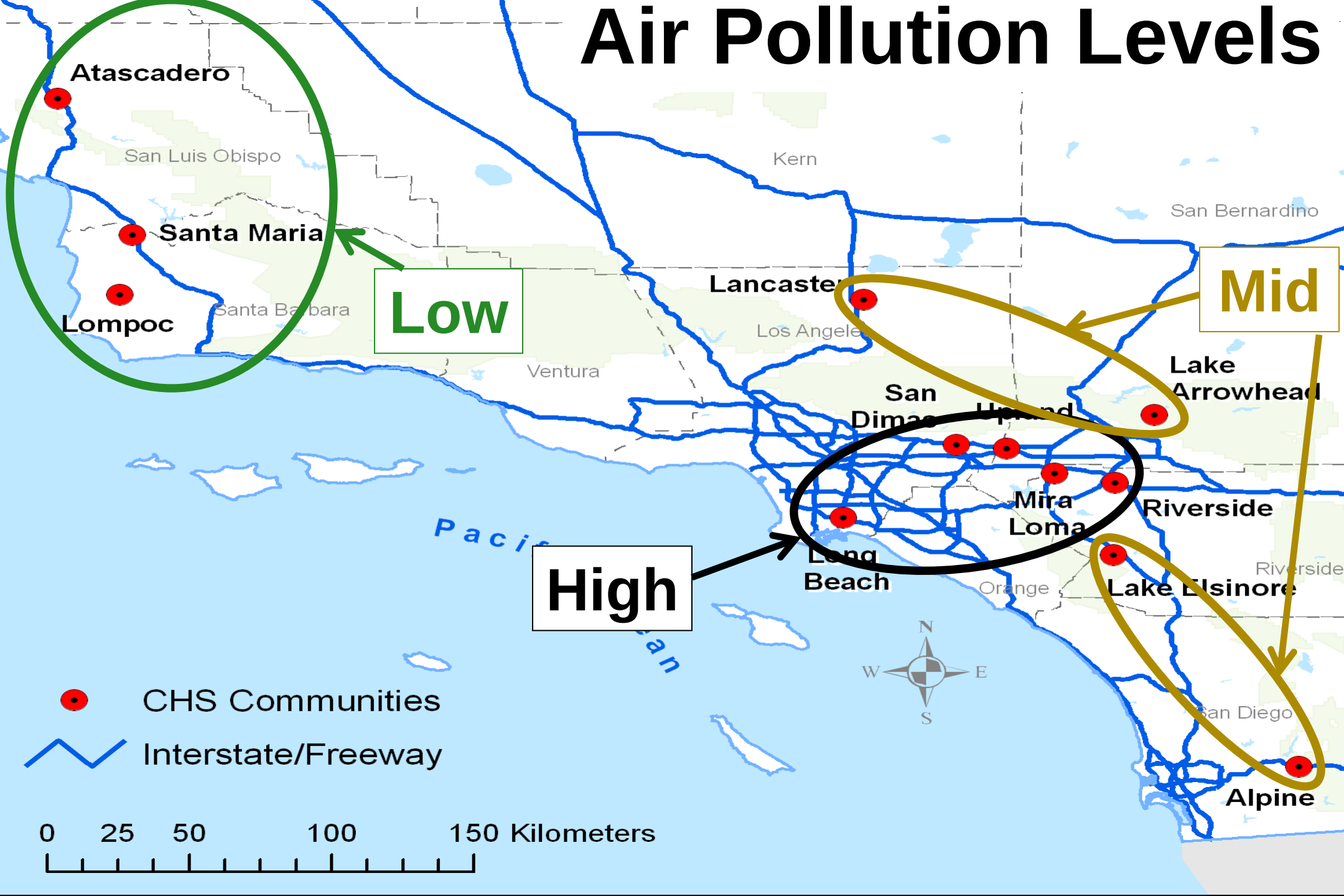


1) Find CA communities with a range of air pollution profiles
2) Recruit volunteers & “measure” their health for ***years***
4) Measure air pollution at the same time
5) See if changes in health are related to changes in pollution

Study Communities

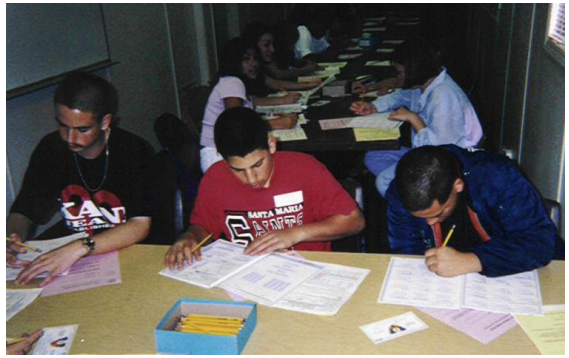


Air Pollution Levels



CHS Cohorts, By School Year & Class Grade

Co-hort	N	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
												School Year											
A	938	10	11	12																			
B	937	7	8	9	10	11	12																
C	1806	4	5	6	7	8	9	10	11	12													
D	2081				4	5	6	7	8	9	10	11	12										
E	5603											K/1	1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	9/10	10/11	11/12
E+	324												1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	9/10	10/11	11/12
(ALL)	11689																						



Annual Spirometry

Lung function measures:

- Forced expiratory volume in first second of exhalation (FEV_1)
- Forced vital capacity (FVC)
- Maximal mid-expiratory flow (MMEF)
- Peak expiratory flow rate (PEFR)

Annual Questionnaires about health & home operating characteristics

Active smoking?

Height?

Weight?

Pets?

Asthma?

Gas stove?

Respiratory illnesses?

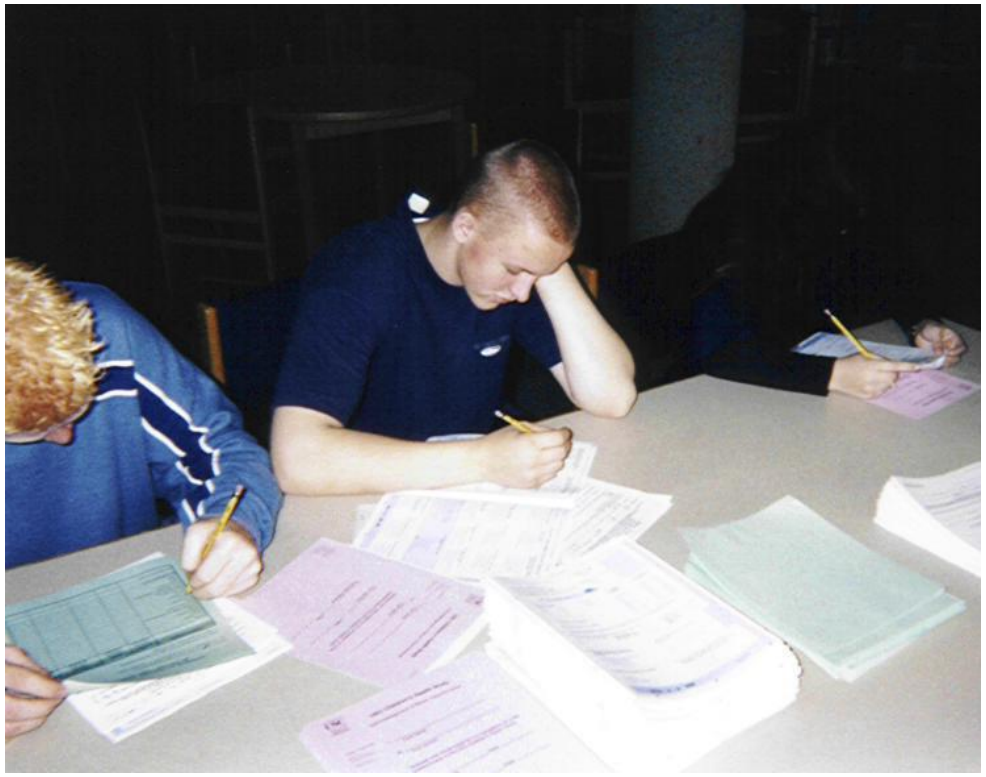
Passive Smoking?

Exercise?

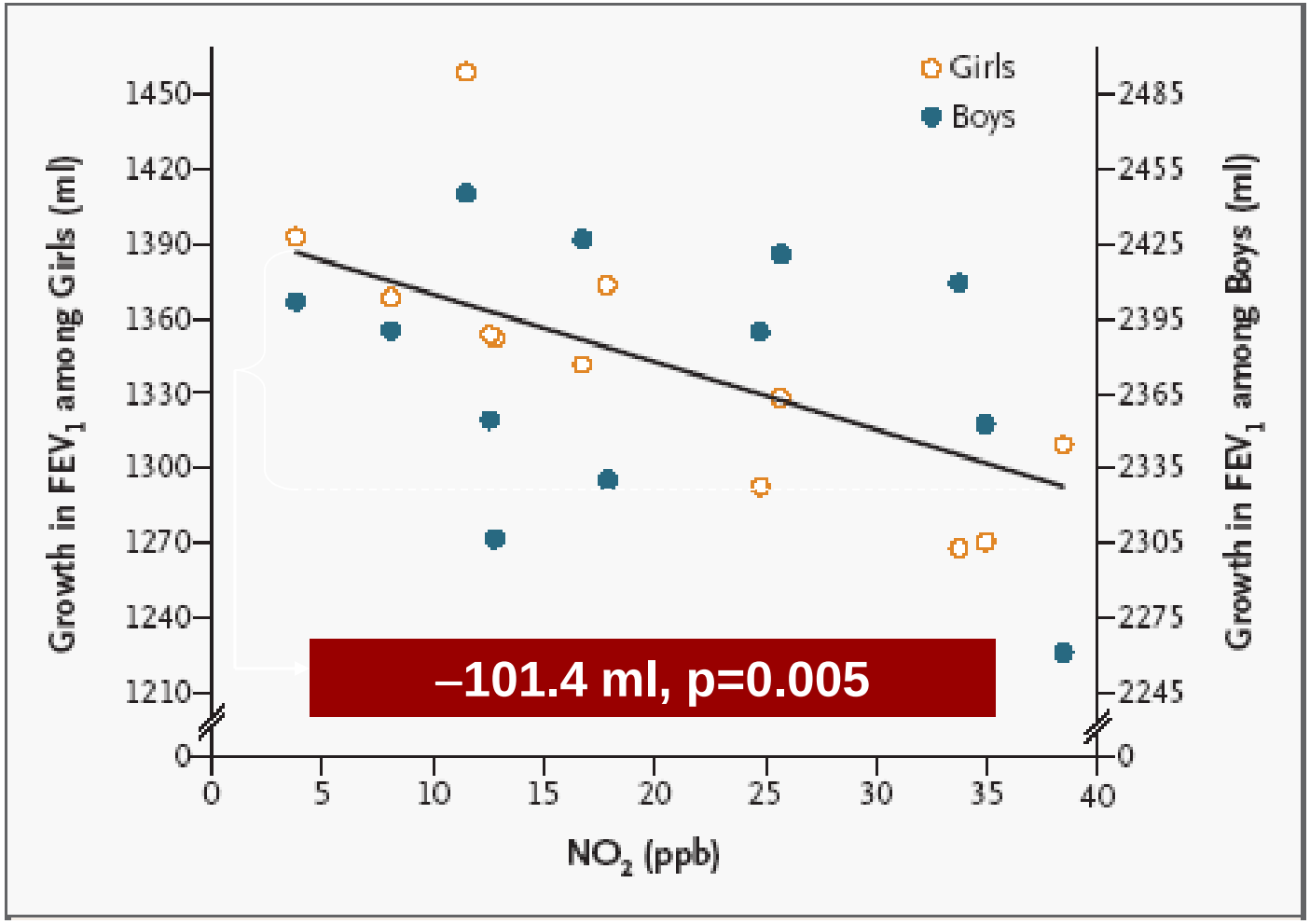
mold?

Diet

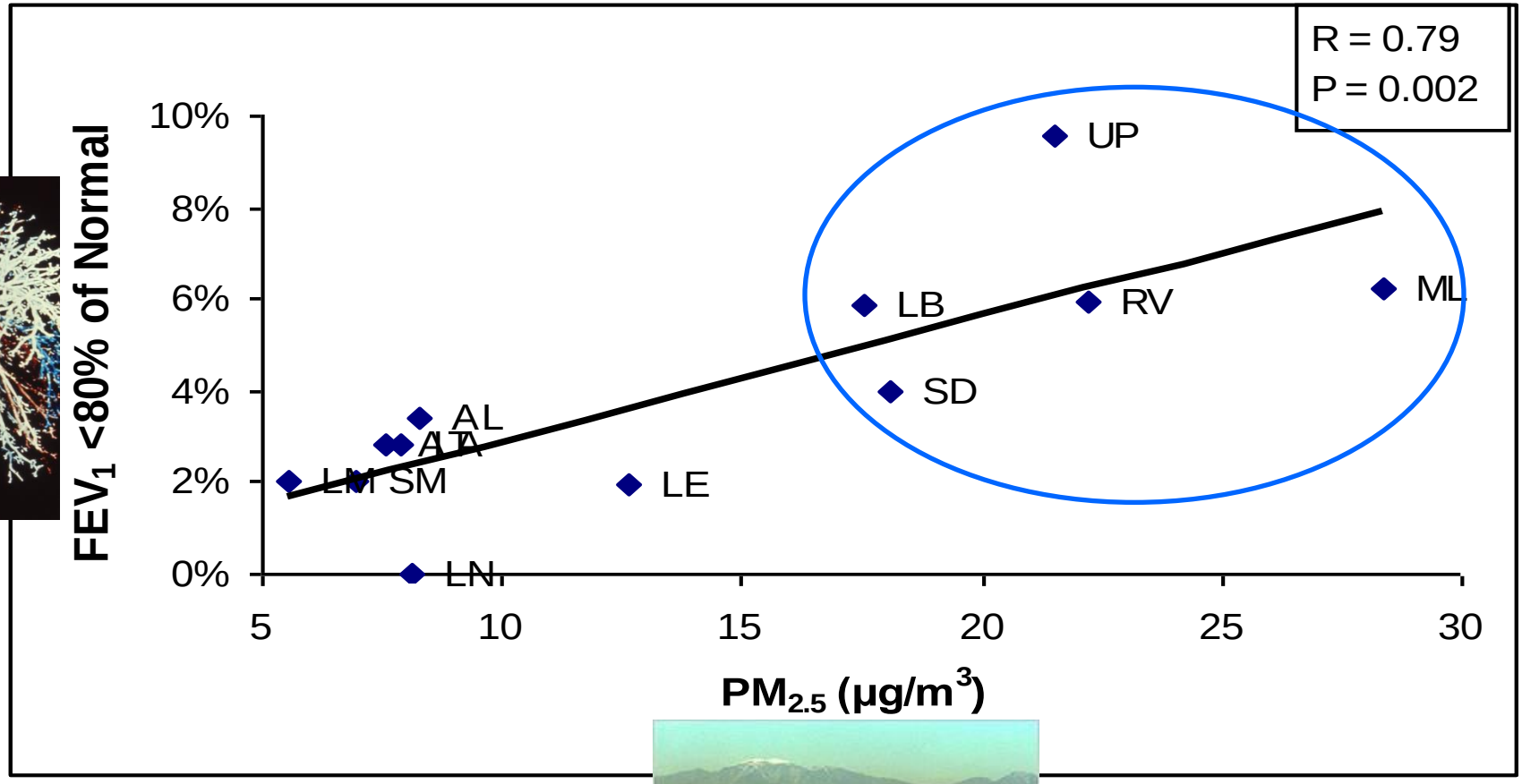
Medication?



8-yr FEV_1 Growth in Girls and Boys vs. 7-year average NO_2 levels

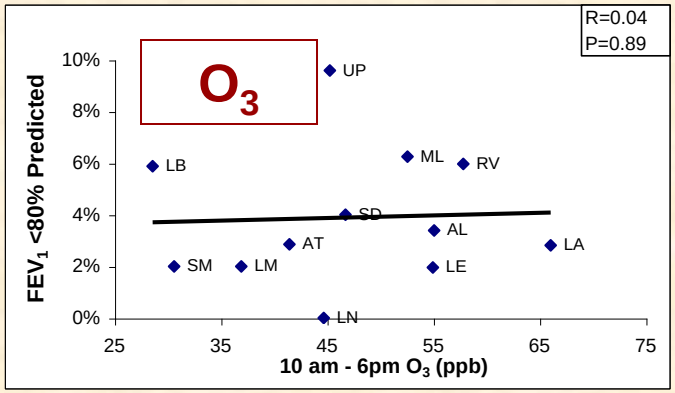


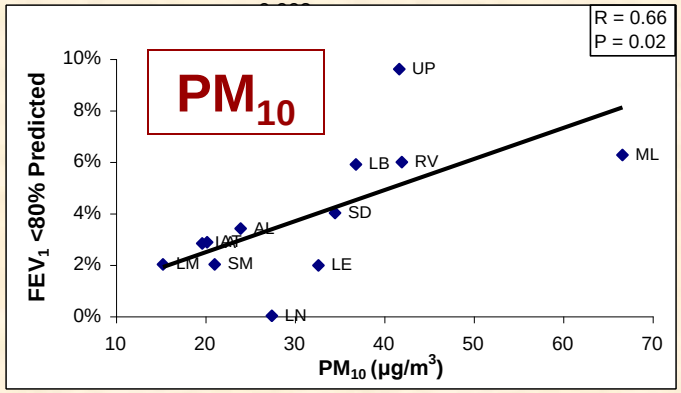
Abnormally Low Lung Function is More Likely in a Polluted Community

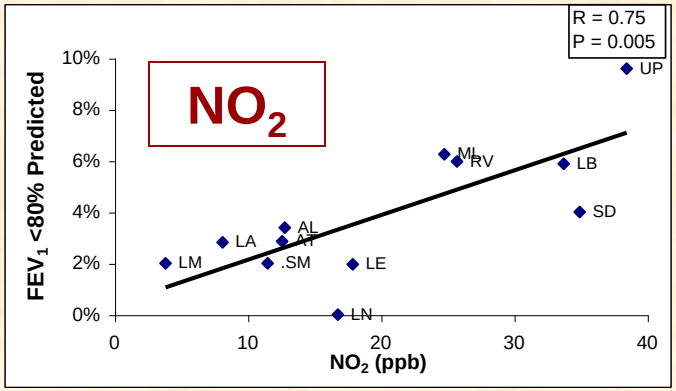


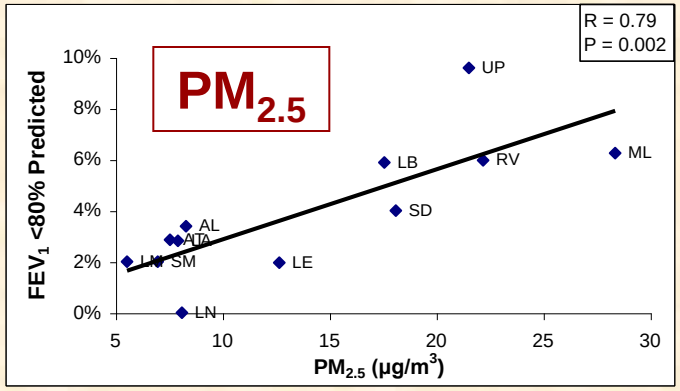
Gauderman et al., NEJM, 2004

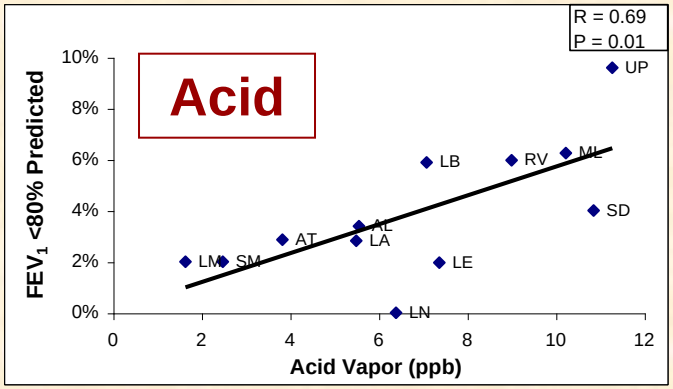
Low FEV_1 at Age 18 vs. Pollution

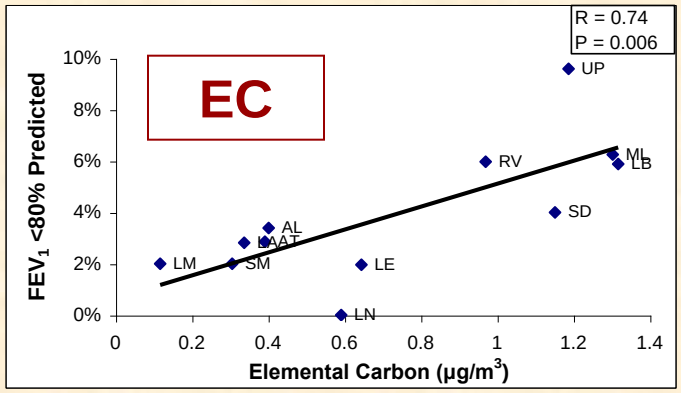












The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 SEPTEMBER 9, 2004 VOL. 351 NO. 11

The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age

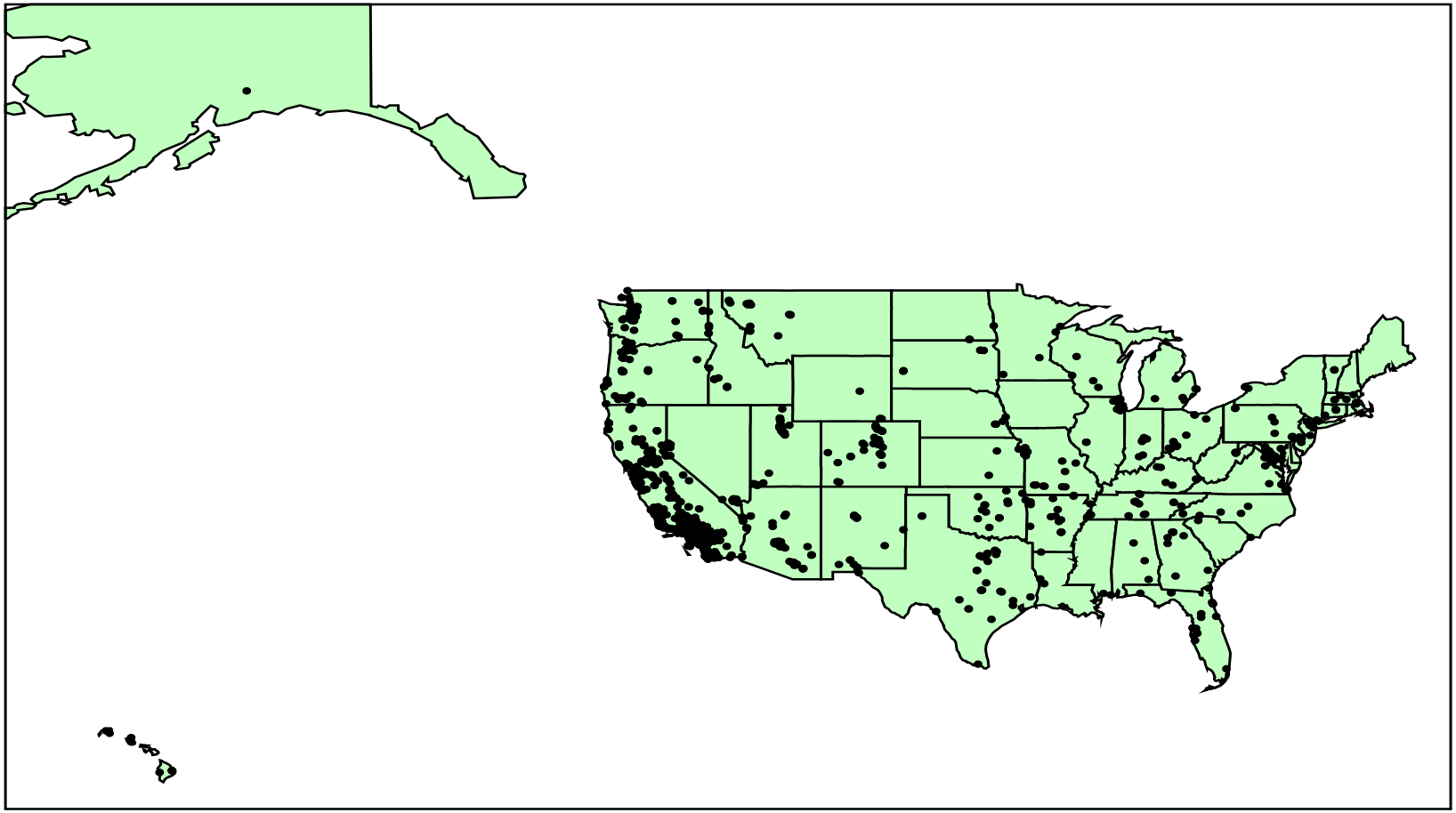
W. James Gauderman, Ph.D., Edward Avol, M.S., Frank Gilliland, M.D., Ph.D., Hita Vora, M.S., Duncan Thomas, Ph.D., Kiros Berhane, Ph.D., Rob McConnell, M.D., Nino Kuenzli, M.D., Fred Lurmann, M.S., Edward Rappaport, M.S., Helene Margolis, Ph.D., David Bates, M.D., and John Peters, M.D.

CONCLUSIONS

The results of this study indicate that current levels of air pollution have chronic, adverse effects on lung development in children from the age of 10 to 18 years, leading to clinically significant deficits in attained FEV_1 as children reach adulthood.

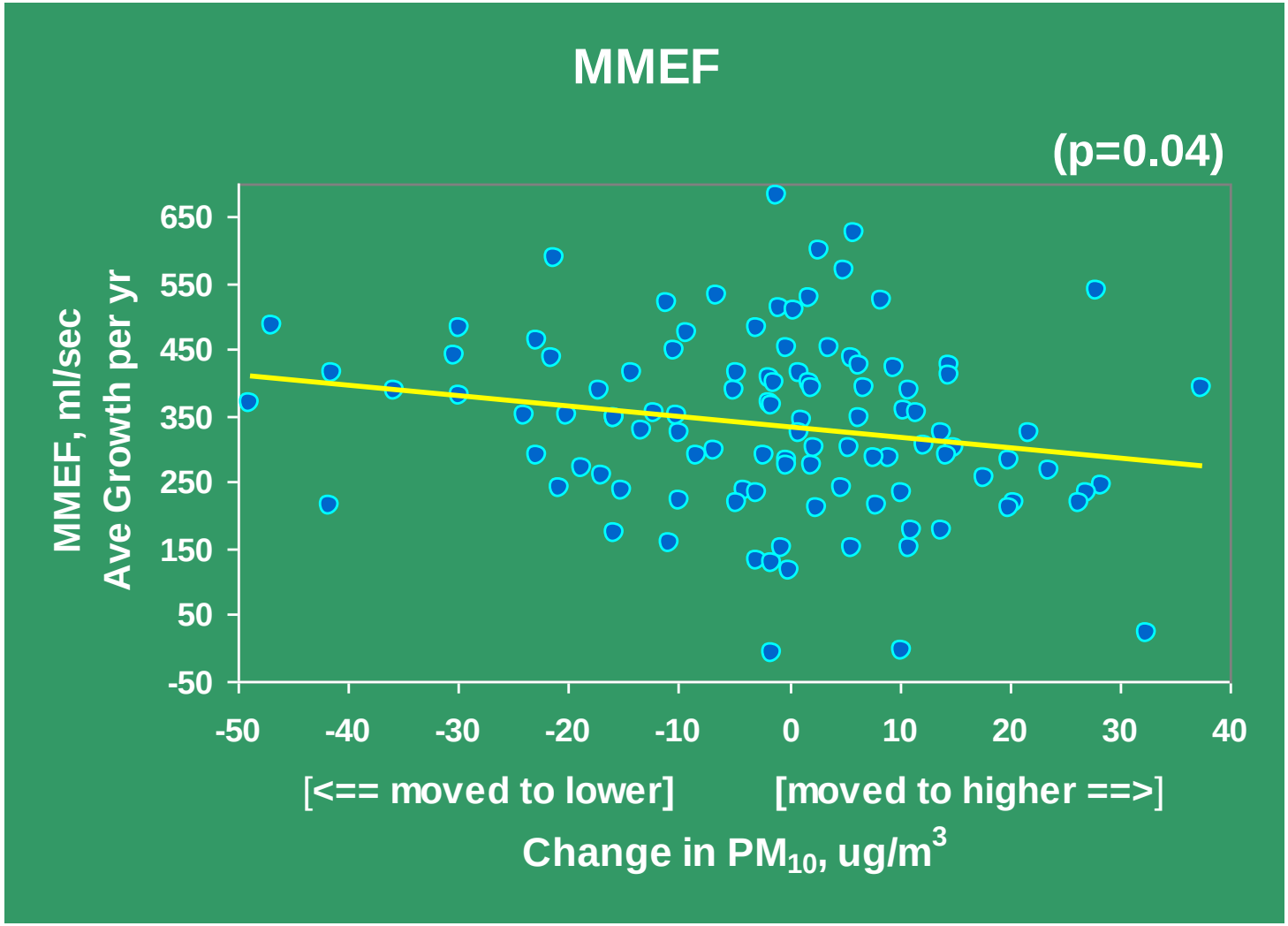
CHS Movers Study

What happens to health when children move?



… Some to higher pollution, some to lower …

Lung Function Growth in Movers



(Avol et al., 2001)

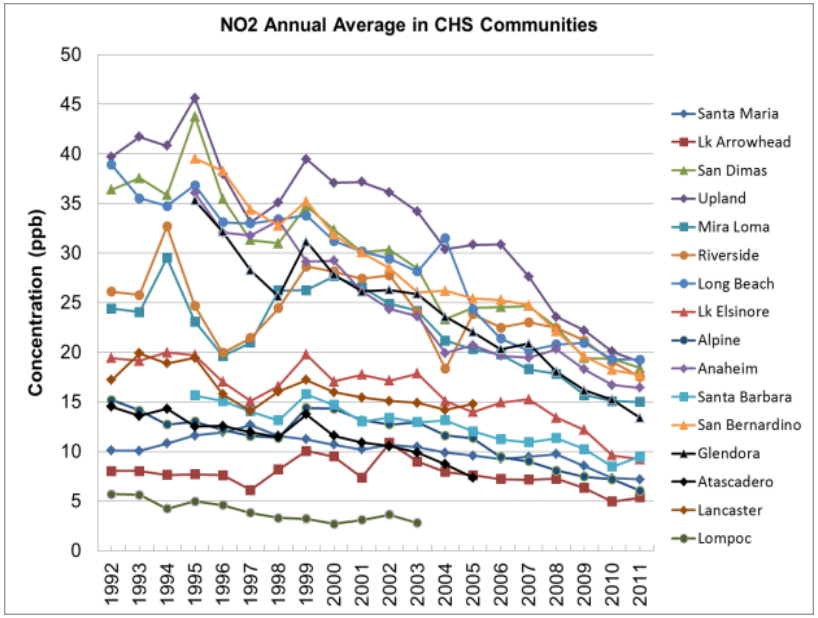
But what if, over time,

the air got *cleaner*

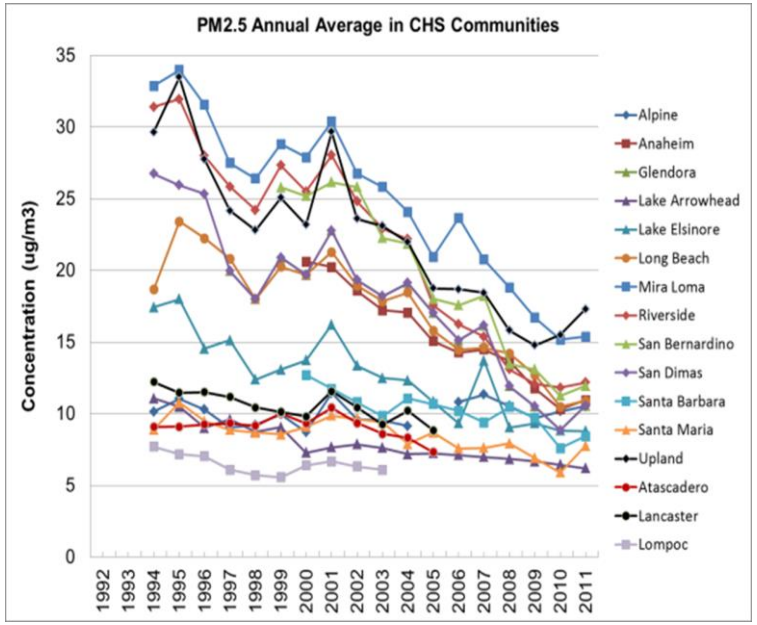
where they stayed & grew up?

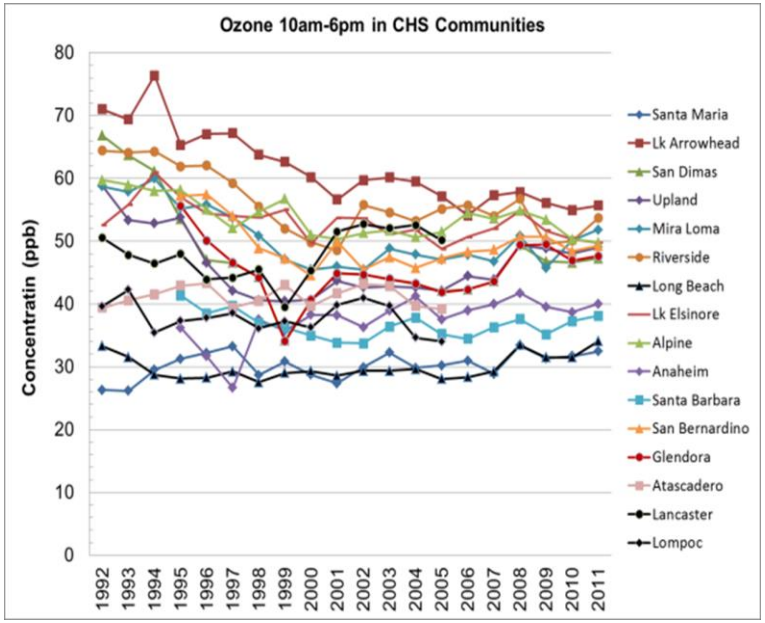
Air Quality Improved

Between 1994 & 2011, annual average NO_2 *declined* 28% to 53%!



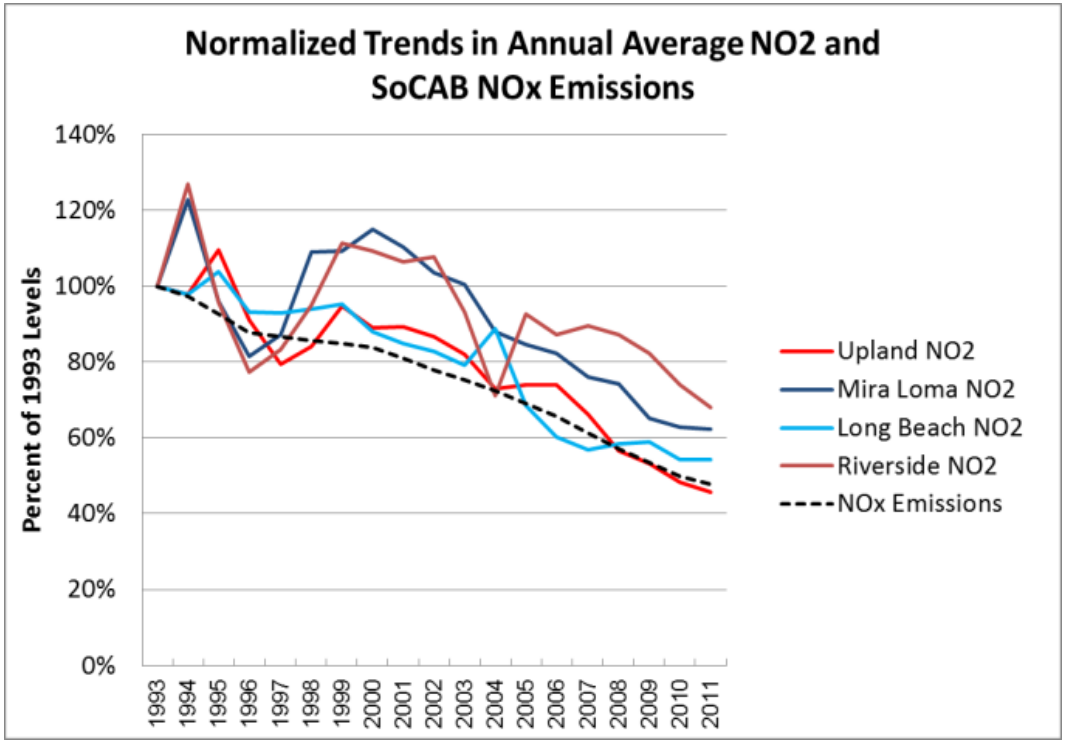
Annual average $PM_{2.5}$ *declined* 13% to 54%!

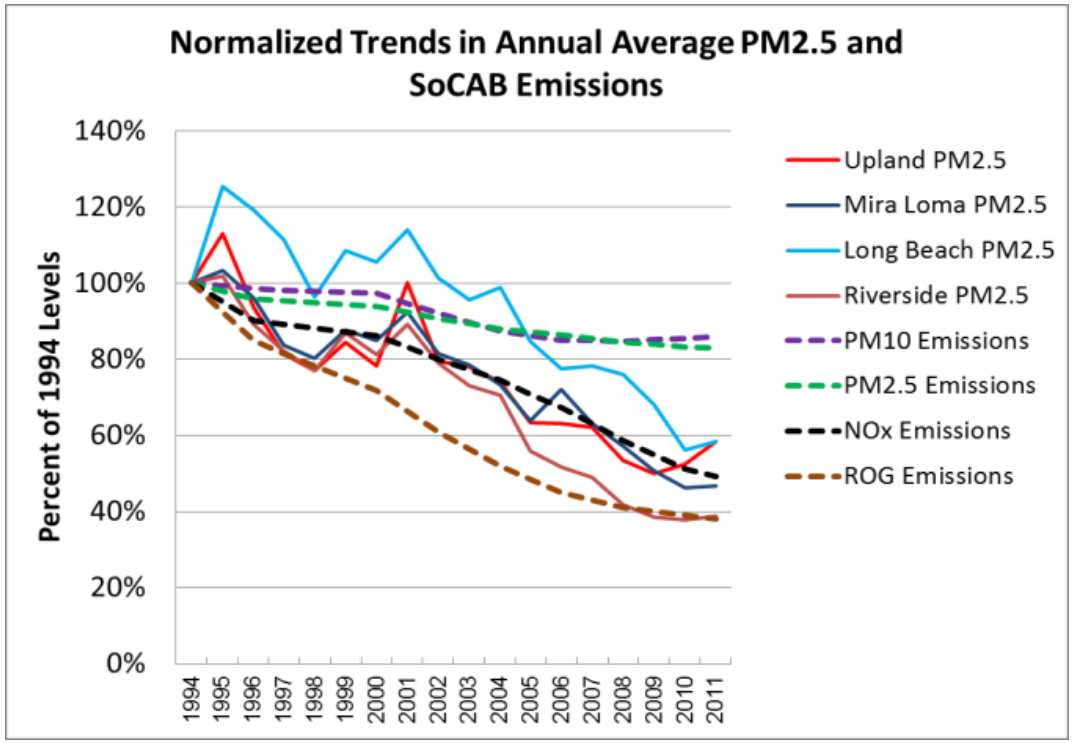




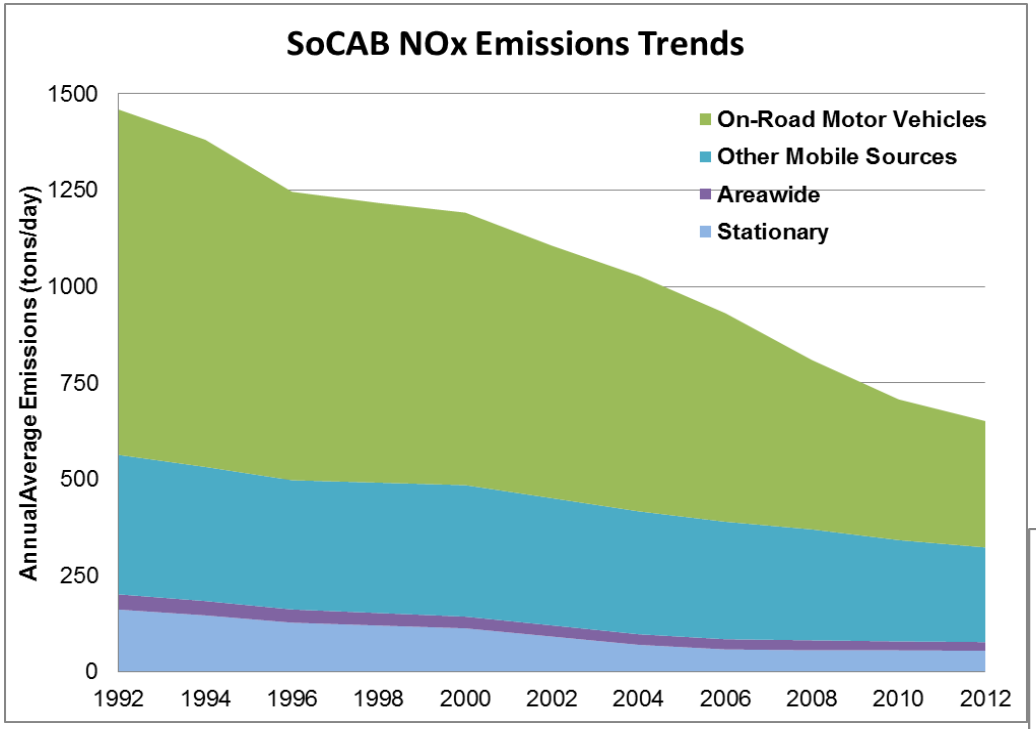
Average O_3 declines were much more moderate (or increased slightly)

NOx & PM Emissions Decreased …



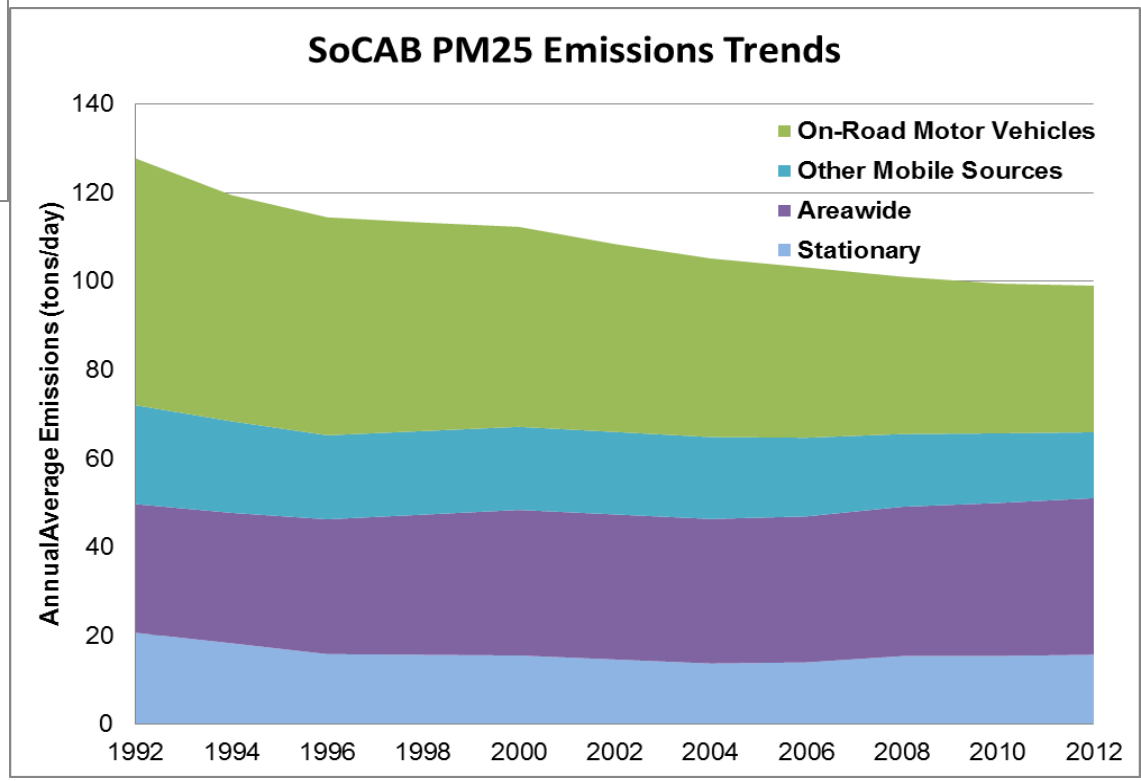


("Normalized" to baseline values in 1993 for NO_2, 1994 for $PM_{2.5}$)



On-road motor vehicles

accounted for majority of decreased emissions (1992-2012)



HOW did they
?
"do" THAT?

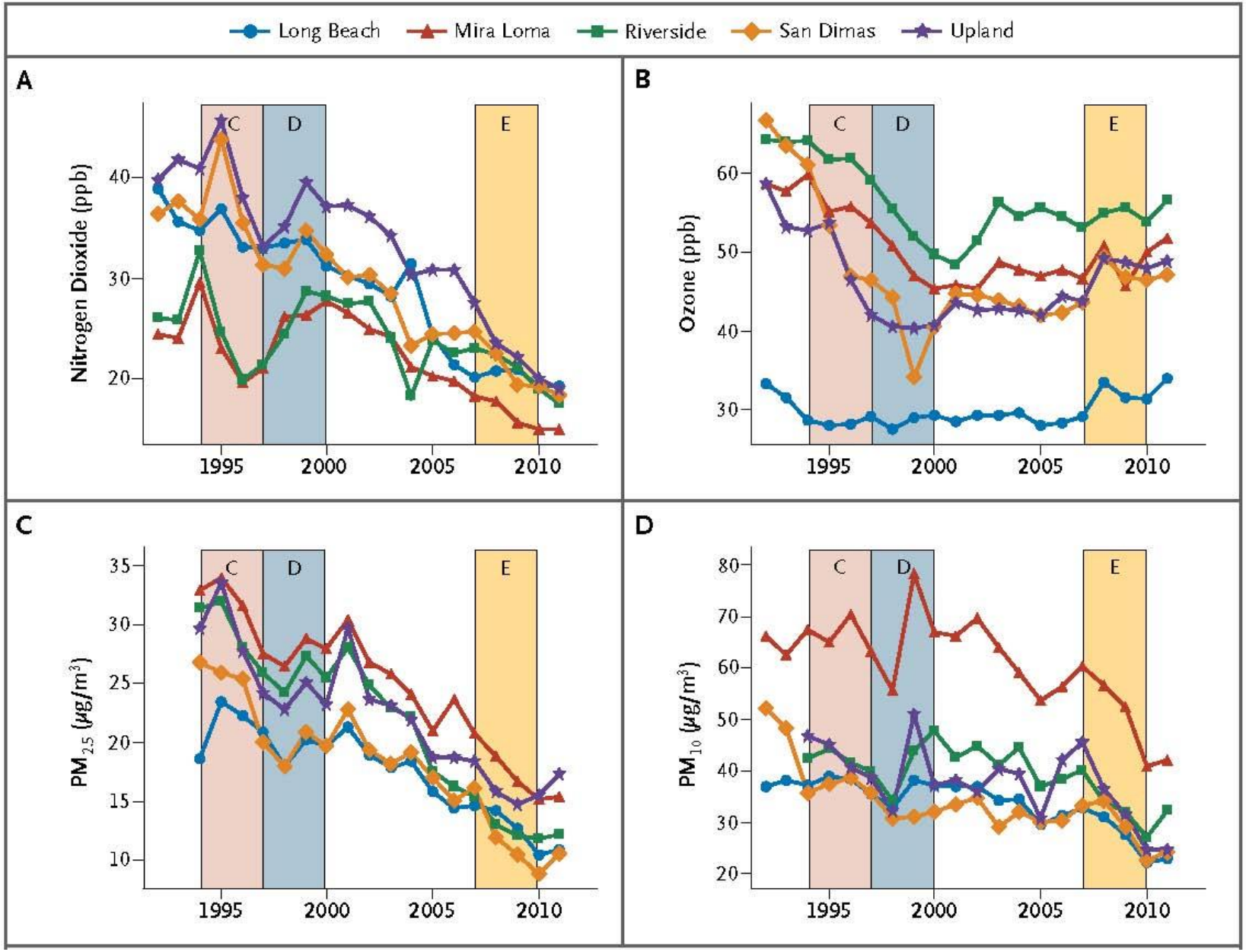
By the early 1990s, most stationary sources in the South Coast Air Basin had been pretty well-controlled…

in California (1985-2012)

Regulatory Policy	Adoption Date
On-road Emissions:	
Low-emission vehicle standards for light-duty and medium-duty vehicles (LEV, LEV II)	1990, 1998
Reformulated gasoline	1988, 1990, 1991
On-board diagnostics standards for light-duty vehicles	1985, 1989
Medium-duty and heavy-duty truck gasoline emission standards	1995
Heavy-duty diesel truck engine emissions standards	1998, 2001
Clean diesel fuel requirements	2003
Financial incentives for replacement or retrofit high-polluting vehicles, engines & equipment (e.g., the Carl Moyer Program)	1998-2012
Cleaner port (drayage) trucks	2007
Off-Road Emissions:	
Cleaner diesel fuel for ocean-going vessels, harbor craft, and trains	2004, 2008
Reduced port auxiliary engines and incinerator use, hoteling	2007
Cleaner locomotive engines in Southern California	1997, 2010
Stationary diesel engines standards for in-use agricultural engines	2007
Stationary Point Sources:	
NOx and SOx reductions from *RE*gional *CL*ean *A*ir *I*ncentives *M*arket (RECLAIM)	1994
New Source Review (NSR)	1990
Source-specific emissions standards	1988-2002
Area Sources:	
Low-emission certificate programs for products and equipment	1988-2012
Unpaved and paved road dust control measures	2008
Water heater and small boiler emission standards	1999, 2004

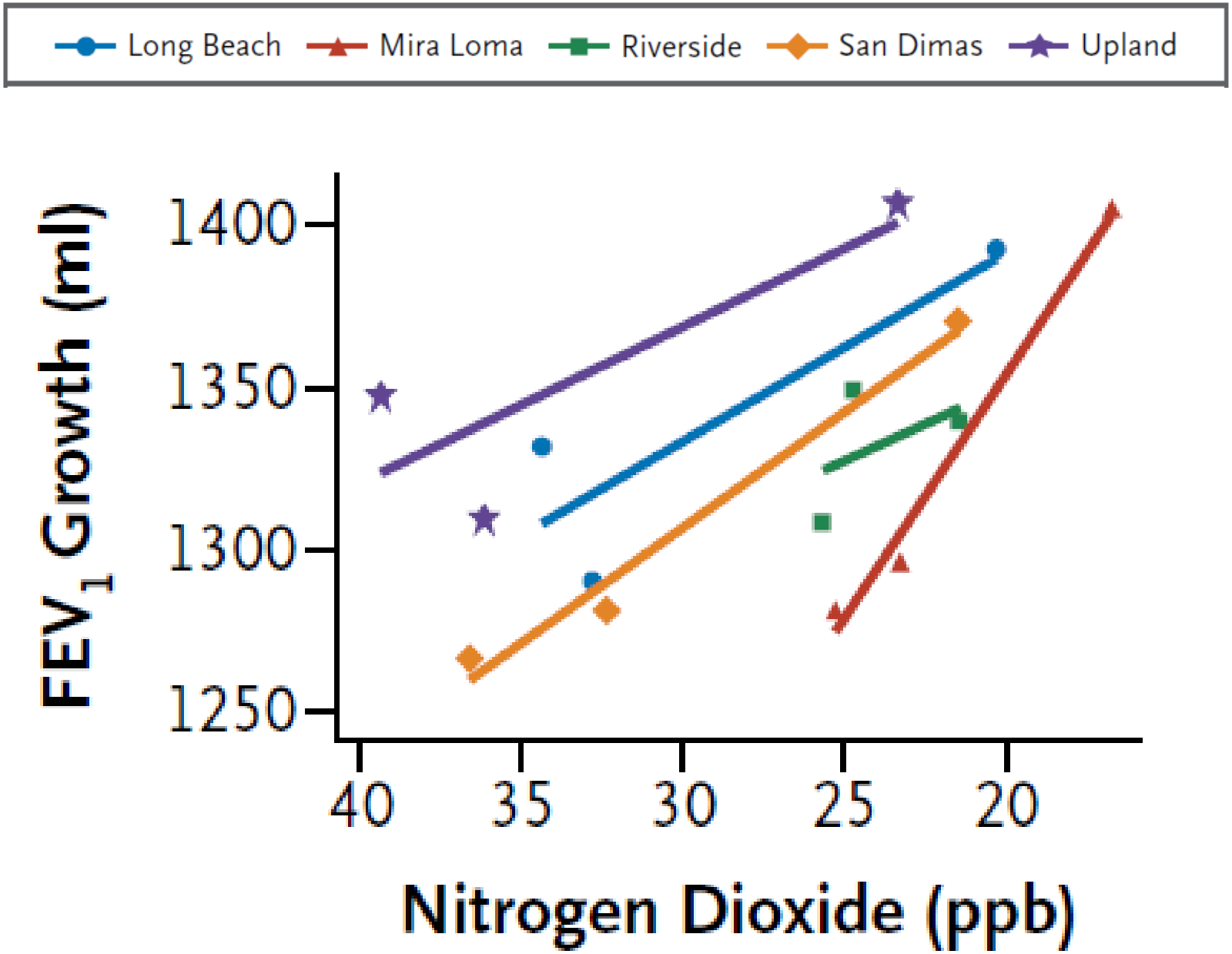
…Did *cleaner* air make a difference in children's health?

Comparable Age Windows (11-15yrs) for CHS Cohorts C,D,E



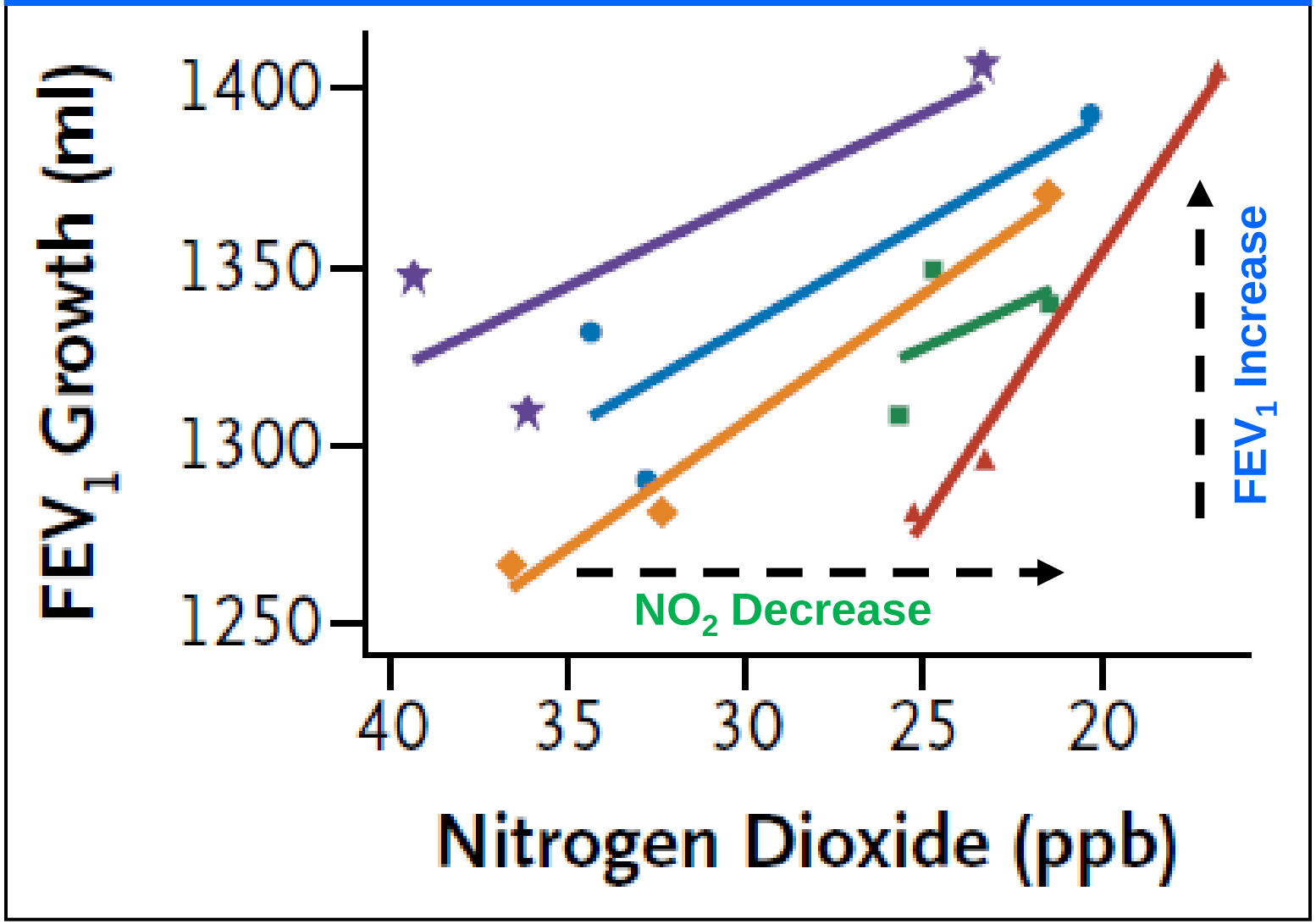
Improved air quality led to better lung function growth…

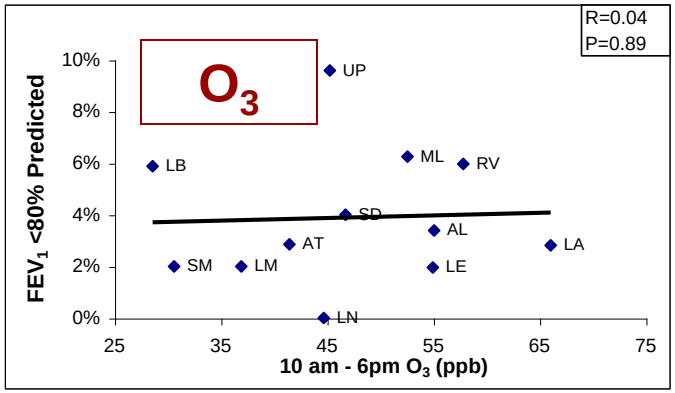
in all 5 towns

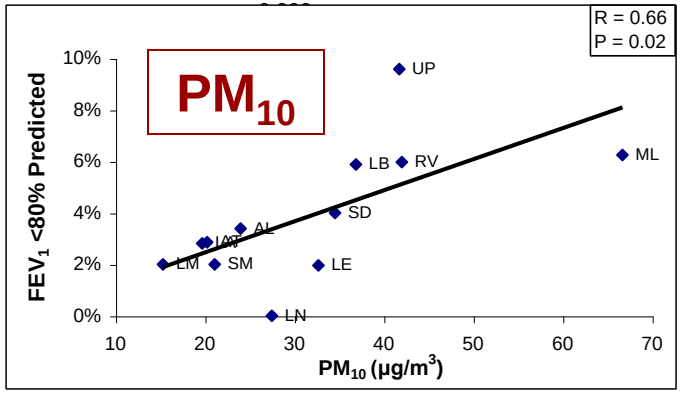


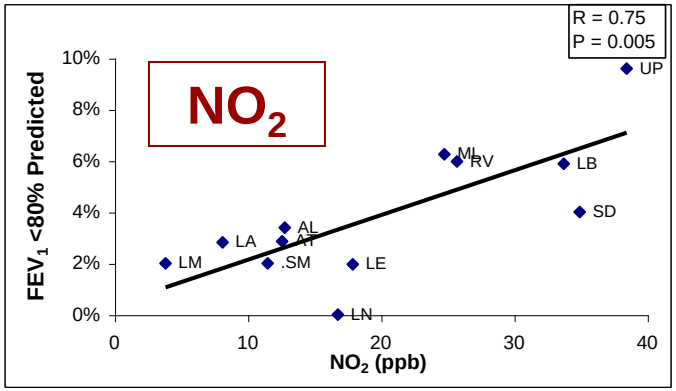
On average:

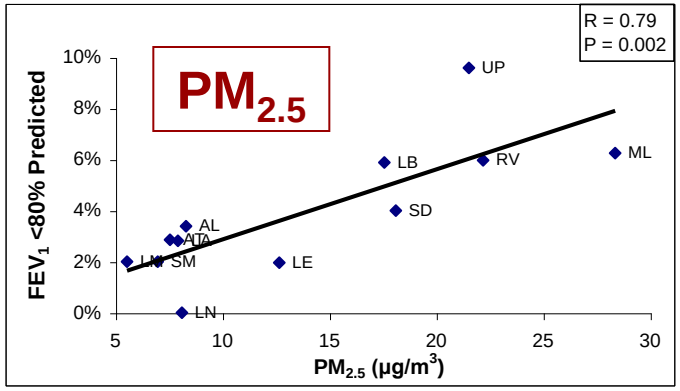
- 14.1 ppb Decrease in NO_2
- 91.4 ml Increase in FEV_1 growth ($p<0.001$)

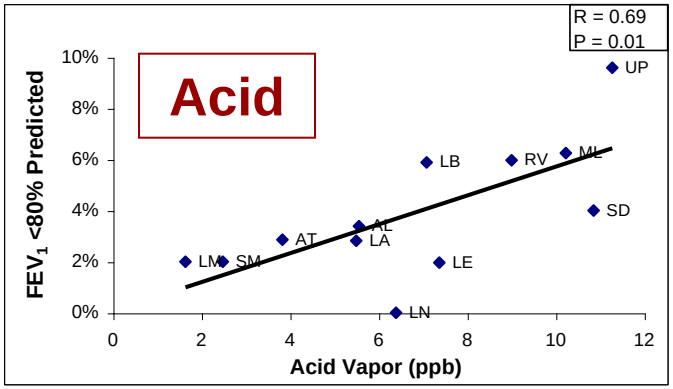


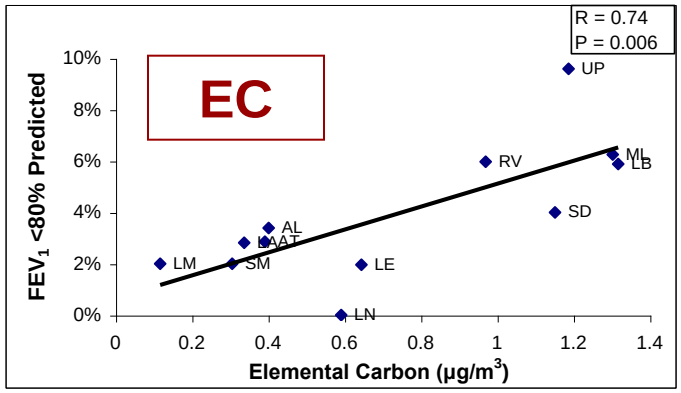

R=0.04
P=0.89
O3
FEV1 <80% Predicted
10 am - 6pm O3 (ppb)
UP
ML
RV
LB
SD
AL
AT
LA
SM
LM
LE
LN


R = 0.66
P = 0.02
PM10
FEV1 <80% Predicted
PM10 (µg/m3)
UP
ML
LB
RV
SD
AL
AT
LM
SM
LE
LN

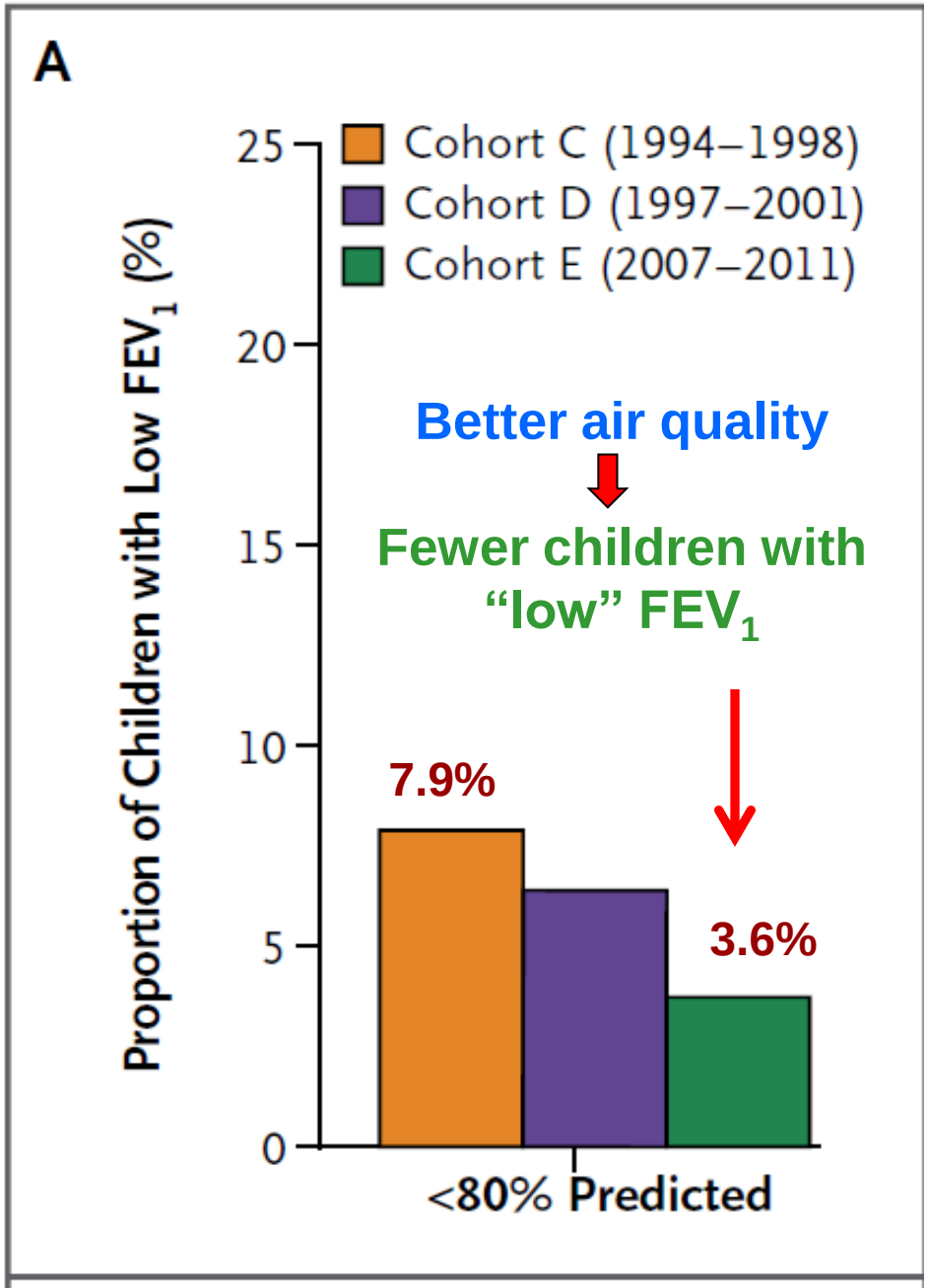

R = 0.75
P = 0.005
NO2
FEV1 <80% Predicted
NO2 (ppb)
UP
ML
RV
LB
SD
AL
LA
AT
LM
.SM
LE
LN


R = 0.79
P = 0.002
PM2.5
FEV1 <80% Predicted
PM2.5 (µg/m3)
UP
LB
RV
ML
SD
AL
ATA
SM
LE
LN


R = 0.69
P = 0.01
Acid
FEV1 <80% Predicted
Acid Vapor (ppb)
UP
LB
RV
ML
SD
AL
LA
AT
LM
SM
LE
LN


R = 0.74
P = 0.006
EC
FEV1 <80% Predicted
Elemental Carbon (µg/m3)
UP
ML
LB
RV
SD
AL
AT
LM
SM
LE
LN

As air quality improved, the percent of children with low FEV_1 at age 15 decreased!



NEJM, 2015

USC

Emissions reduction policies and recent trends in Southern California's ambient air quality

JAWMA, 65:3, 324-335, (2015)

Fred Lurmann,[1] Ed Avol,[2,*] and Frank Gilliland[2]
[1] *Sonoma Technology, Incorporated, Petaluma, CA, USA*
[2] *Department of Preventive Medicine, University of Southern California, Los Angeles, CA, USA*
[*] *Please address correspondence to: Ed Avol, Department of Preventive Medicine, University of Southern California, 2001 N. Soto St, Los Angeles, CA 90089, USA; e-mail: avol@usc.edu*

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MARCH 5, 2015 VOL. 372 NO. 10

Association of Improved Air Quality with Lung Development in Children

W. James Gauderman, Ph.D., Robert Urman, M.S., Edward Avol, M.S., Kiros Berhane, Ph.D., Rob McConnell, M.D., Edward Rappaport, M.S., Roger Chang, Ph.D., Fred Lurmann, M.S., and Frank Gilliland, M.D., Ph.D.

The NEW ENGLAND JOURNAL of MEDICINE

EDITORIAL

Cleaner Air, Bigger Lungs

Douglas W. Dockery, Sc.D., and James H. Ware, Ph.D.

In the latter half of the 20th century, Los Angeles had, by many measures, higher levels of photochemical air pollutants than any other major city in the United States (Fig. 1). To address this problem, the California Air Resources Board and its partners became leaders in quantifying the growth in the children recruited in 1993,[2] 1997,[4] and 2003.[5]

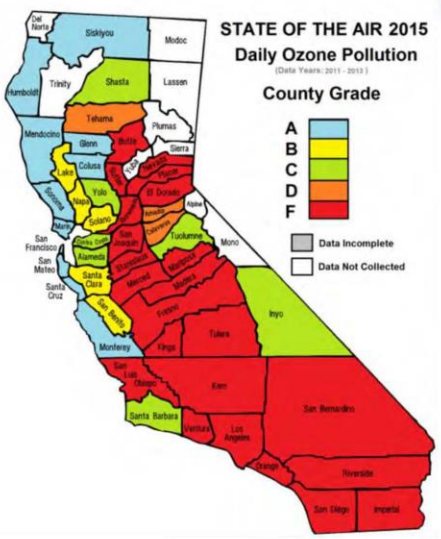
The consistency of findings in the three separate cohorts is compelling. Moreover, the investigators sought to minimize the potential for confounding by controlling for known individual

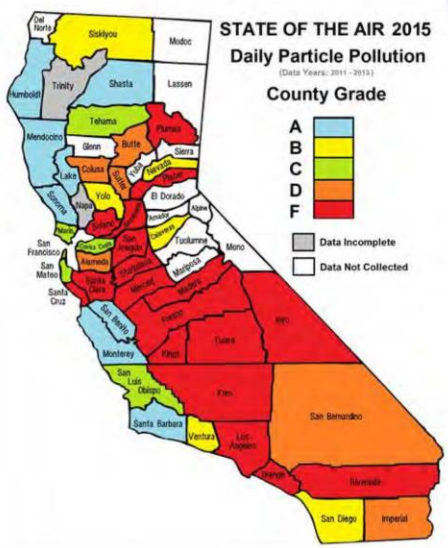
Original Investigation JAMA® The Journal of the American Medical Association

Association of Changes in Air Quality With Bronchitic Symptoms in Children in California, 1993-2012

Kiros Berhane, PhD; Chih-Chieh Chang, PhD; Rob McConnell, MD; W. James Gauderman, PhD; Edward Avol, MS; Ed Rapapport, MPH; Robert Urman, PhD; Fred Lurmann, MS; Frank Gilliland, MD, PhD

JAMA. 2016;315(14):1491-1501. doi:10.1001/jama.2016.3444





But…
Los Angeles is not "clean" yet

Top US Cities (Highest Air Pollution)

2016 American Lung Association "State of the Air" Report

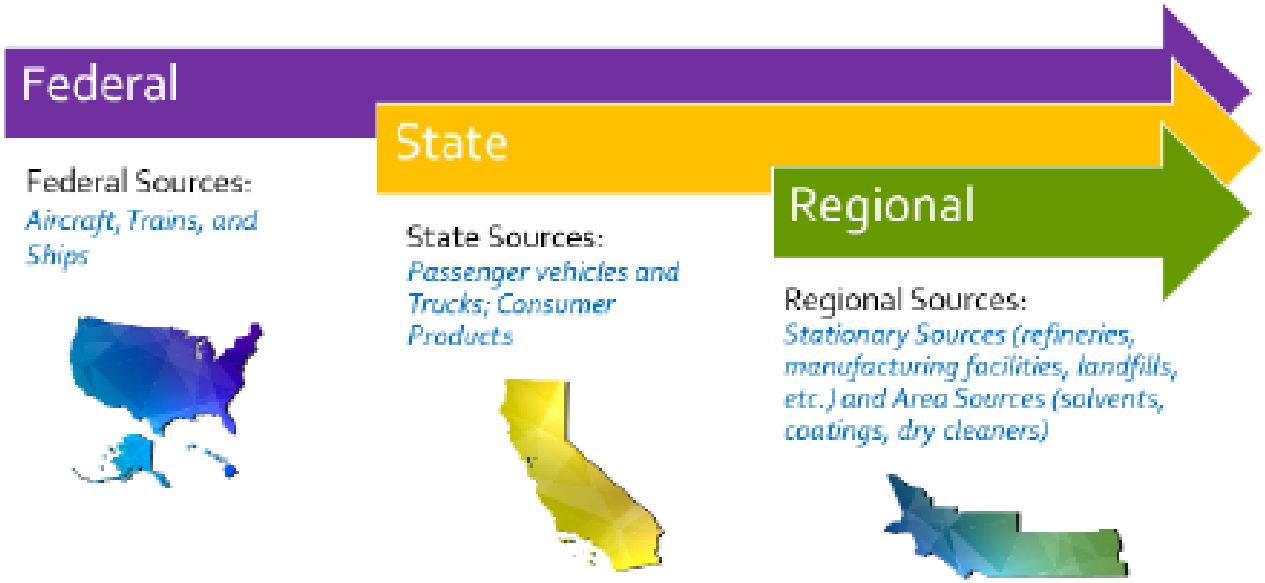
Year-Round PM		Ozone	
1	Bakersfield CA	1	Los Angeles-Long Beach CA
2	Visalia-Porterville-HanfordCA	2	Bakersfield CA
3	Fresno-Madera CA	3	Visalia-Porterville-HanfordCA
4	Los Angeles-Long Beach CA	4	Fresno-Madera CA
5	El Centro CA	5	Phoenix-Mesa-Scottsdale AZ
6	Modesto CA	6	Sacramento-Roseville CA
6	San Jose- San Francisco-Oakland CA	7	Modesto-Merced CA
8	Pittsburgh-New Castle-Weirton PA-OH-WV	8	Denver-Aurora CO
9	Harrisburg-York-Lebanon PA	9	Las Vegas-Henderson NV
10	Louisville-Jefferson KY	10	Fort Collins CO

http://www.lung.org/about-us/media/press-releases/2016-state-of-the-air.html

"Compliance" (meeting national outdoor air standards) is going to take more time…

Standard	Concentration	Classification	Latest Attainment Year
2008 8-hour Ozone	75 ppb	Extreme	2031
2012 Annual PM2.5	12 μg/m³	Serious*	2025
2006 24-hour PM2.5	35 μg/m³	Serious	2019
1997 8-hour Ozone	80 ppb	Extreme	2023
1979 1-hour Ozone	120 ppb	Extreme	2022

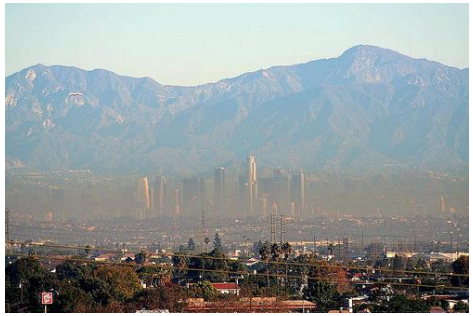
* The 2016 AQMP requests a reclassification from moderate to serious non-attainment for this standard



From 20Jan2017 Fact Sheet, http://www.aqmd.gov/home/library/clean-air-plans/air-quality-mgt-plan

Summary

- Air quality IS improving
  & emissions ARE being reduced in “La-La Land”
- These improvements *are* reflected in
  improved respiratory health of children
- Cleaning up the air does makes a *measurable* difference
- There’s still more to do (NAAQS compliance for PM & O_3)



vehicle exhaust is more than just cars!

Children's Health Study (CHS)

Funded by:

California Environmental Protection Agency
Air Resources Board

NIH National Institute of Environmental Health Sciences

National Institutes of Health

United States Environmental Protection Agency

HEI

The Hastings Foundation

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Aerosol Dynamics, Inc

South Coast Air Quality Management District

San Diego Air Pollution Control District

San Luis Obispo/Tri-Counties Air Pollution Control District

Mojave Air Pollution Control District

Antelope Valley Air Pollution Control District

California Air Resources Board

Questions???

Ask me now, or at avol@usc.edu

4-Yr Lung Function Growth vs. Pollution Decreases

Lung Function	Pollutant	Growth, age 11 to 15 Difference		P-value
FEV_1	→ NO_2	91.4	(47.9, 134.9)	<0.001
	O_3 (10-6)	-6.7	(-51.0, 37.5)	0.77
	→ PM_{10}	65.5	(27.2, 103.7)	<0.001
	→ $PM_{2.5}$	65.5	(17.1, 113.8)	0.008
FVC	→ NO_2	168.9	(127.0, 210.7)	<0.001
	O_3 (10-6)	-7.3	(-79.3, 64.6)	0.84
	→ PM_{10}	113.1	(60.0, 166.1)	<0.001
	→ $PM_{2.5}$	126.9	(65.7, 188.1)	<0.001

Estimated differences in lung function growth are scaled to decreases of 14.1 ppb in NO_2, 5.5 ppb in O_3 (10 am - 6 pm), 8.7 $\mu g/m^3$ in PM_{10}, and 12.6 $\mu g/m^3$ in $PM_{2.5}$